practically ubiquitous appearance in a germinating and adult condition. The presence of putrefiable or putrescent matter determines at once the germination of the always-present spore. But a new question arises. These spores are definite products. In the face of some experimental facts one was tempted to inquire, have these spores any capacity to resist heat greater than the adults? It was not easy to determine this question. But we at length were enabled to isolate the germs of seven separate forms, and by means of delicate apparatus, and some twelve months of research, to place each spore sac in an apparatus so constructed that it could be raised to successive temperatures, and without any change of conditions examined on the stage of the microscope.

In this way we reached successive temperatures higher and higher until the death point—the point beyond which no subsequent germination ever occurred—was reached in regard to *each* organism. The result was striking. The normal death point for the adult was 140° F. One of the monads emitted from its sac minute mobile specks—evidently living bodies—which rapidly grew. These we always destroyed at a temperature of 180° F. Three of the sacs emitted spores that germinated at every temperature under 250° F. Two more only had their power of germination destroyed at 260° F. And one, the least of all the monad forms, in a heat partially fluid and partially dry, at all points up to 300° F. But if wholly in fluid it was destroyed at the point of 290° F. The average being that the power of heat resistance in the spore was to that of the adult as 11 to 6. From this it is clear that we dare not infer spontaneous generation after heat until we know the life-history of the organism.

In proof of this I close with a practical case. A trenchant and resolute advocate of the origin of living forms *de novo*, has published what he considers a crucial illustration in support of his case. He took a strong infusion of common cress, placed it in a flask, boiled it, and, whilst boiling, hermetically sealed it. He then heated it up in a digester to 270° F. It was kept for nine weeks and then opened, and, in his own language, on microscopical examination of the earliest drop "there appeared more than a dozen very active monads." He has fortunately measured and roughly drawn these. A facsimile of his drawing is here. He says that they were possessed of a rapidly moving lash, and that there were other forms without tails, which he assumed were developmental stages of the form. This is nothing less than the monad whose life-history I gave you last. My drawings, magnified 2500 diams., of the active organism and the developing sac, are here.

Now this experimenter says that he took these monads and heated them to a temperature of about 140° F., and they were all absolutely killed. This is accurately our experience. But he says these monads arose in a closed flask, the fluid of which had been heated up to 270° F. Therefore, since they are killed at 140° F., and arose in a fluid after being heated to 270° F., they must have arisen *de novo!* But the truth is that this is the monad whose spore only loses its power to germinate at a temperature (in fluid) of 290°, that is to say, 20° F. higher than the heat to which, in this experiment, they had been subjected. And therefore the facts compel the deduction that these monads in the cress arose, not by a change of dead matter into living, but that they germinated naturally from the parental spore which the heat employed had been incompetent to injure. Then we conclude with a definite issue, viz., by experiment it is established that living forms do not now arise in dead matter. And by study of the forms themselves it is proved that, like all the more complex forms above them, they arise in parental products. The law is as ever, only that which is living can give origin to that which lives.

WHIRLWINDS AND WATERSPOUTS [1]

WHIRLWINDS, whether on sea or on land, have their characters in great part alike. For simplicity it will be convenient to begin by taking up only the case of whirlwinds on sea, as thus the necessity for alternative expressions to suit both cases, that of sea and that of land, will be avoided.

It may be accepted as a fact sufficiently established, both by dynamic theory and by barometric observations, that at the sea-level the pressure of the air is less in the neighbourhood of the axis of whirl than it is at places farther out from the axis, though within the region of the whirl. The apocentric force (centrifugal force) of the rapidly-revolving air resists the inward pulsive tendency of the greater outer than inner pressure. But close over the surface of the sea there exists necessarily a lamina of air greatly deadened as to the whirling motion by fluid friction, or resistance, against the surface of the sea; and all the more so because of that surface being ruffled into waves and often broken up into spray. This frictionally-deadened lamina exerts, because of its diminished whirl speed, less apocentric force than the quicker-revolving air above it, and so is incapable of resisting the inward pulsive tendency of the greater outer than inner pressure already mentioned. Hence, while rushing round in its whirl, the air of that lamina must also be flowing in centreward.

The influx of air so arriving at the central region cannot remain there continually accumulating; it is not annihilated, and it certainly does not escape downwards through the sea. There is no outlet for it except upwards, and as a rising central core it departs from that place. This is one way of thinking out some of the conditions of the complex set of actions under contemplation; but there is much more yet to be considered.

Hitherto, in the present paper, nothing has been said as to the cause or mode of origin of the diminished barometric pressure which, during the existence of the whirlwind, does actually exist in the central region. Often in writings on this subject the notion has been set forth that the diminished pressure is caused by the rapid gyratory motion of the whirling air; but, were we to accept that view, we would have still to ask, How does the remarkably rapid whirling motion receive its own origin? The reply must be that the view so offered is erroneous; and that, in general, a diminished pressure existing at some particular region is the cause rather than the effect of the rapid whirling motion; though in some respects indeed these two conditions can be regarded as being mutually causes and effects, each being essential to the maintenance of the other, while there are also some further promoting causes or conditions not as yet here mentioned.

It seems indubitably to be the truth that ordinarily for the genesis of a whirlwind the two chief promoting conditions are: firstly, a region of diminished barometric pressure, this diminution of pressure being, it may be presumed, due to rarefaction of the atmosphere over that region by heat, and sometimes, further, by its condition as to included watery vapour; and, secondly, a previously existing revolutional motion, or differential horizontal motion, of the surrounding air, such revolutional or differential motion being not necessarily of high velocity at any part.

The supposed accumulation of air rarefied by heat or otherwise, for producing the abatement of pressure may, the author supposes, in some cases extend upwards throughout the whole depth of the atmosphere; and in some cases may be in the form of a lower warm lamina which somehow may have been overflowed or covered by colder air above, through which, or into which, it will tend to ascend: or the lower lamina may in some cases be warmed in any of several ways, and so may get a tendency to rise up through the colder superincumbent atmosphere. On this part of the subject the author believes there is much scope for further researches and advancements both observational and considerational;—that is to say, by encouragement of a spirit towards accurate observation; and by collection and scrutiny of observed facts and appearances; and by careful theoretical consideration founded on observational results or suppositions.

To the author it seems probable that the great cyclones may have their region of rarefied air extending up quite to the top of the atmosphere; while often whirlwinds of smaller kinds, many of the little dust whirlwinds, for instance, which are frequently to be seen, may terminate, or gradually die out, at top in a layer or bed of the atmosphere different in its conditions, both as to temperature and as to original motion, from the lower layer in which the whirlwind has been generated. In many such cases the upper air may probably be cooler than the lower air in which the whirlwind originates.

On the subject of the actions going on at the upper parts or upper ends of whirlwind cores in most cases, the author feels that he is able to offer at present little more than suggestions and speculative conjectures. In very many descriptions of the appearances presented by those whirlwinds with visible revolving cores, which are called waterspouts, it is told that the first appearance of the

[1] Paper by James Thomson, LL.D., D.Sc., Professor of Civil Engineering and Mechanics in the University of Glasgow, read in Section A, at the British Association meeting at Montreal, on Monday, September 1.

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so-called waterspout consists in the rapid shooting down from a dense cloud of a black cloudy streak, seemingly tortuously revolving and swaying more or less sidewise. This is said rapidly to prolong itself downwards till it meets the surface of the sea; and the water of the sea is often imagined and described as rising up bodily, or as being drawn up, into the partial vacuum or central columnar place of diminished pressure. The frequently entertained notion—a notion which has even made its way into writings by men of science and of authority in meteorology—that the water of the sea is sucked up as a continuous liquid column in the centre of waterspout whirlwinds, is by some writers and thinkers repudiated as being only a popular fallacy, and it is affirmed that it is only the spray from the broken waves that is carried up. In this denial of the supposition of the water being sucked up as a continuous liquid column the author entirely agrees, and he agrees in the opinion that spray or spindrift from the sea set into violent commotion by the whirlwind is carried up in a central ascending columnar core of air.

On the other hand, the commonly-alleged inception of the visible waterspout phenomena, in a descending, tortuously-revolving, and laterally-bending or swaying cloudy spindle protruding from a cloud, the author supposes to be so well accredited by numerous testimonies that it must be seriously taken into account in the development of any true theory and explanation of the physical conditions and actions involved. He ventures to hazard a suggestion at present—perhaps a very crude and rash one. It is that the rising central core may perhaps, in virtue of its whirling motion and centrifugal tendency, afford admission for the cloudy stratum to penetrate down as an inner core within that revolving ascending core now itself become tubular. The cloudy stratum may be supposed not originally to have been endowed with the revolutional motion or differential horizontal motion with which the lower stratum of thermally expanded air has been assumed to be originally endowed. The upper stratum of air from which the cloudy spindle core is here taken to protrude down into the tubular funnel is not to be supposed to be cold enough to tend to sink by mere gravity. Though it were warm enough to allow of its floating freely on the thermally expanded air below, it could still be sucked down into the centre of the revolving ascending core of the whirlwind.

Not to proceed further on this occasion with attempts towards explanation of the difficult subject of the actions at the upper ends of waterspout whirlwinds, the author wishes to have it understood that his main object in proceeding to prepare the present paper was to put forward clearly the theory he has given as to influx at the bottom in consequence of abatement of whirl in the lamina close to the sea-surface by frictional resistance there.

Addendum.—A few brief explanations and references will now be added to assist in the understanding of some of the principles assumed in what has been already said. It is to be clearly understood that, in a whirling fluid, even if the velocity of the whirling motion be very small at great distances from the axis, if the fluid be impelled inwards by forces directed towards the axis, the absolute velocity will greatly increase with diminution of distance from the axis. Thus in the *whirlpool of free mobility*, in which the particles are perfectly free to move outward or inward, the velocities of the particles are inversely proportional to the distances from the axis, the fluid being understood to be inviscid or frictionless. On this subject reference may be made to a paper by the author on "Whirling Fluids," published in the British Association volume for the Belfast Meeting, 1852. Again, as to the inward flow caused in a frictionally retarded bottom lamina of a whirlwind or whirlpool with vertical axis, by the frictional retardation from the bottom on which the whirling fluid rests, reference may be made to a paper by the author, "On the Grand Currents of Atmospheric Circulation" in the British Association Report, Dublin Meeting, 1857, part ii. p. 38. On another case of the manifestation of the same principle, reference may be made to a paper by the author in the *Proceedings* of the Royal Society for May 1876, in respect to the "Flow of Water round Bends in Rivers, &c.," with reference to the effects of frictional resistance from the channel in the bends; and to another paper by him, on the same subject, in the *Proceedings* of the Institution of Mechanical Engineers (August 1879, p. 456), where the inward flow is explained as experimentally exhibited.

Postscript of date August 16.—Prof. James Thomson wishes now to offer in continuation of his paper on "Whirlwinds and Waterspouts," despatched two days ago for Montreal the following postscript, which will extend the considerations there already put forward, and will tend to modify or amend some of them; but will leave unchanged the theory as to influx of the bottom lamina of the whirlwind towards the central region in consequence of the frictional resistance offered by the surface of the sea to the air whirling in close contiguity upon that surface.

He wishes to put forward the question as to whether it may not be possible, in some cases of whirlwinds, for the barometric pressure in the central or axial region to become abated through the combined influences of rarefaction by heat (increased, perhaps, by conditions as to included moisture) on the one hand, and the whirling motion on the other hand, very much beyond the abatement that could be due to heat, or heat and moisture, alone, without the whirling motion. He thinks it very likely that in great whirlwinds, including those which produce the remarkable phenomena called waterspouts, it may be impossible for the whirling action to be confined to the lower region of the atmosphere; but that, even if commenced there, it would speedily be propagated to the top. It seems also not unlikely, and in some trains of thought it comes to appear very probable, that the whirling fluid, ascending by its levity, would drive outwards from above it all other air endowed with less whirling energy, and would be continually clearing away upwards and outwards the less energetic axial core which enters from below, and any, if such there be, that has entered from above. He is unable at present to offer much in further elucidation (possibly it might only prove to be in further involvement) of this very difficult subject. He thinks the question should at least be kept open as to whether the whirling and scouring action may not go forward growing more and more intense, promoted always by energies from the thermal sources which have produced differences of temperature and moisture in different parts of the atmosphere, and that thus a much nearer approach to vacuum in the centre may be caused than would be due merely to the levity of the superincumbent air if not whirling.

He also wishes to suggest that the dark and often frightful cloud usually seen in the early stages of whirlwinds and waterspouts, and the dark columnar revolving core often seen apparently protruding downwards from the cloud, may be due to precipitation of moisture into the condition of fog or cloud, on account of abatement of pressure by ascension in level, and environment with whirling air, which by its centrifugal tendency acts in protecting the axial region from the pressure inwards of the surrounding atmosphere.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

CAMBRIDGE.—Dr. Besant and Mr. C. H. Prior are appointed Moderators, and Messrs. C. Graham and A. J. C. Allen Examiners, in the Mathematical Tripos for the year beginning May 1, 1885.

The following Natural Science Examiners have been appointed:—Physics: Prof. A. Schuster and Mr. W. N. Shaw; Chemistry: Messrs. A. Scott and M. Pattison Muir; Mineralogy: Prof. Lewis and Mr. H. P. Gurney; Geology: Messrs. R. D. Roberts and J. J. H. Teall: Botany: Messrs. F. Darwin and H. M. Ward; Zoology: Prof. A. M. Marshall and Mr. A. Sedgwick; Human Anatomy: Prof. A. Macalister and Mr. A. Hill; Physiology: Prof. Michael Foster and Mr. J. N. Langley.

St. John's College offers for competition in December next a large number of Open Scholarships, Exhibitions, and Sizarships. Natural Science is one of the subjects which, taken singly, may lead to election to any of these. The subjects are in general those of the Natural Sciences Tripos; but every candidate in Natural Science must show a competent knowledge of two at least of the following subjects:—Physics, Chemistry, and Biology, all in an elementary sense. A candidate, however, may be elected on the ground of special proficiency in any one of the subjects of examination. There will be both papers and practical work in all subjects. Further information may be obtained from the tutors.

Trinity College Examinations begin on December 11. Major and Minor Scholarships, Exhibitions, and Sizarships may be given for Natural Science. One Exhibition at least, of the value of 50*l.*, will be given for Natural Science to a candidate not yet in residence at the University.

King's College offers an Exhibition of 60*l.* per annum for Natural Science: examination on December 11.

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